

The Incretin Effect And Its Significance – Basic To Applied Physiology

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Abstract: The gastrointestinal tract releases several hormones in response to oral food intake and absorption. The increased secretion of insulin in response to oral glucose administration when compared to intravenous glucose administration is called the Incretin effect. This is due to release of certain gut hormones which in turn cause an increased glucose stimulated insulin secretion. The incretin effect is due to two main hormones: Glucose-dependent Insulinotropic Polypeptide (GIP) and Glucagon-like Peptide – 1 (GLP-1). The insulinotropic effect of GLP-1 is preserved in type 2 diabetic patients. Since GLP-1 is rapidly degraded by the plasma enzyme Dipeptidyl Peptidase IV (DPP-IV), GLP-1 receptor agonists and DPP-IV inhibitors are now being used to treat type 2 diabetes.

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Introduction: Intake of food is associated with release of several hormones from the gastrointestinal mucosa¹. These hormones exert several physiological effects and thus play important roles in maintaining normal homeostasis¹. Knowledge of the structure, stimulus for release, mechanism of action and functions of these gut hormones is crucial for understanding normal physiology, pathophysiology and planning treatment strategies for various disease conditions. Among various gut hormones, a few of them affect insulin secretion and thus play a role in diabetes mellitus^{2,3,4}.

Type 2 diabetes is a major health problem all over the world⁵. The incidence of type 2 diabetes in India is on the increase⁶. Effective management of this disease is essential in order to avoid the multiple complications associated with it. Novel treatment strategies are being researched in order to treat this disease satisfactorily. This non-systematic or journalistic review focuses on the incretin effect and the inroads it has made in the treatment of type 2 diabetes mellitus. The journal articles that were reviewed were accessed using the PubMed search engine and the inter-library loan policy.

Incretin effect: In the early 1960s, experiments were conducted to compare amount of insulin secretion in response to oral versus intravenous glucose administration^{7,8}. These experiments revealed that oral glucose caused greater insulin secretion when compared to glucose given intravenously^{7,8}. This increased amount of insulin secretion with orally administered glucose when compared with intravenously administered glucose is called the ‘Incretin effect’^{7,9}. There is

approximately two to three fold increase in insulin secretion due to the incretin effect in normal people⁸. Research was further extended to find out the cause for the incretin effect. This led to the possibility that oral glucose caused release of certain gut hormones which in-turn stimulated insulin secretion. Studies done as early as the 1960s proved this hypothesis right^{2,3}. The gut hormones responsible for the incretin effect are called **incretin hormones**¹⁰.

Incretin hormones: The main gut hormones which are responsible for the incretin effect were found to be **Glucose-dependent Insulinotropic Polypeptide (GIP)**² also called Gastric Inhibitory Polypeptide and **Glucagon-like Peptide – 1 (GLP-1)**¹¹. They are both responsible equally for the incretin effect¹². They are peptide hormones and are released in response to absorption of food. The fasting plasma level of these hormones is less than 10 pmol/L and increases to about 50 pmol/L following food ingestion thus bringing about the incretin effect. Both hormones have a very short half life (ie about 2 minutes for GLP-1 and about 5 minutes for GIP) and are rapidly degraded or cleaved by Dipeptidyl Peptidase IV (DPP-IV) which is a plasma enzyme, and later cleared by the kidneys¹².

Glucagon-like Peptide – 1 (GLP-1) is released by ‘L’ cells, mainly in the mucosa of the distal ileum and colon. It is released in response to absorption of glucose, protein and fat in the diet. GLP-1 exists as two important potent forms i.e. GLP-1₇₋₃₇ amide and GLP-1₇₋₃₆ amide. GLP-1 receptors are located on beta cells, alpha cells and in other tissues¹².

Glucose-dependent Insulinotropic Polypeptide (GIP) is released by 'K' cells mainly in the duodenal mucosa in response to glucose and fat absorption. GIP receptors are located on beta cells and to a lesser proportion in other tissues¹². The principle physiological effects of GLP-1 and GIP are summarized in table 1^{12, 13, 14, 15, 16}.

Table 1: Structural and functional aspects of incretin hormones: Glucagon-like Peptide – 1 (GLP-1) and Glucose-dependent Insulinotropic Polypeptide (GIP)^{12, 13, 14, 15, 16}.

Incretin hormones	GLP-1	GIP
Chemical nature	Peptide	peptide
Different forms	GLP-1 ₇₋₃₇ , GLP-1 ₇₋₃₆ amide.	GIP
Produced in the gastrointestinal mucosa by	'L' cells, mainly in the mucosa of the distal ileum and colon	'K' cells mainly in the duodenal mucosa
Stimulus for secretion	absorption of food in the diet with special References to glucose, protein and fat	absorption of food in the diet with special References to glucose and fat
Effect on insulin gene transcription and synthesis	Increases	Increases
Effect on glucose stimulated insulin secretion	Increases	Increases
Effect on insulin sensitivity	Increases	Increases
Effect on beta cell proliferation or neogenesis	Increases	Increases
Effect on beta cell mass	Increases	Increases
Effect on glucose disposal	Enhances	Not known
Effect on food intake	Decreases	Not known
Effect on satiety	Increases	Not known
Effect on gastric emptying	Decreases	No effect

Effect on glucagon secretion	Decreases	No effect
Effect on body weight	Decreases	Not known

Principal action of incretins: The principal action of the incretin hormones is to augment glucose-stimulated insulin secretion¹⁷. GLP-1 and GIP hormone receptors are situated on beta cells as well as in other tissues¹². Animal studies on mice with inactivated GIP or GLP-1 receptors revealed a marked reduction in the glucose-stimulated insulin secretion and showed an impaired glucose tolerance^{18,19}. This proves that incretin hormones are important hormones for glucose homeostasis.

Both GIP and GLP-1 increase insulin synthesis, increase beta cell proliferation and reduce apoptosis¹². Experimental evidence suggests that GLP-1 increases insulin sensitivity, slows gastric emptying and glucose absorption, inhibits glucagon secretion, reduces food intake and enhances satiety^{12,14}.

Mechanism of action producing the incretin effect: The incretin hormones increase glucose-stimulated insulin secretion from the beta cells by acting on G protein coupled receptors and activating adenylyl cyclase, thus increasing cAMP levels. This causes increased calcium entry into the beta cells which in turn causes exocytosis of the insulin granules causing insulin release¹².

What happens to the incretin effect in Type 2 Diabetes Mellitus? The main features of Type 2 diabetes include insulin resistance and impaired glucose stimulated insulin release¹⁷. The incretin effect was studied in type 2 diabetic patients in order to find the possible causes for the impaired glucose stimulated insulin release. Human clinical studies revealed a marked *decrease in the incretin effect* in type 2 diabetic patients²⁰. This decrease in the incretin effect in type 2 diabetic patients contributes to the impaired glucose tolerance seen in these patients.

Further studies were carried out to see if the decrease in incretin effect seen in type 2 diabetic

patients was due to a decrease in incretin hormone secretion or decrease in the incretin hormone function. Studies in type 2 diabetic patients revealed that GIP secretion was near normal post meals but GLP-1 secretion was markedly reduced²¹.

Studies were conducted to assess if the insulinotropic effect of GLP-1 was preserved in diabetic patients, even though the secretion of GLP-1 was reduced. These studies revealed that the insulinotropic effect of GLP-1 was preserved but slightly reduced in type II diabetic patients but the insulinotropic effect of GIP was greatly reduced²².

Since the insulinotropic effect of GLP-1 was preserved in type 2 diabetic patients further studies were done to assess the effectiveness of GLP-1 in treating type 2 diabetes mellitus. In a study done, intravenous infusion of GLP-1 completely normalized plasma glucose in patients with long-standing type II diabetes²³. However, continuous intravenous infusion is not practical as a long term treatment modality. Though GLP-1 has promising effects, it is rapidly degraded/ cleaved by the enzyme Dipeptidyl Peptidase IV (DPP-IV) and thus cannot be used clinically in the form of GLP-1 per se.

Therefore research was focused on finding GLP-1 receptor agonists which would function as GLP-1 but not get degraded by DPP-IV. Research was also focused on preserving GLP-1 by identifying inhibitors for the enzyme DPP-IV.

GLP-1 receptor agonists: GLP-1 receptor agonists bind to the GLP-1 receptors and bring about the effects of GLP-1 as described previously. They do not get degraded by the enzyme DPP-IV. A prominent GLP-1 receptor agonist identified is Exendin-4²⁴. It is a peptide isolated from saliva of Gila monster (*Heloderma suspectum*)²⁵. It has 50% sequence homology to GLP-1 and is stable against DPP-IV¹⁷.

Exenatide is a synthetic form of exendin-4²⁶. Studies done on type 2 diabetic patients comparing Exenatide and placebo injections as an additional treatment to previously prescribed treatment revealed a significant reduction in

HbA1C and significant decrease in body weight with Exenatide²⁷. Thus Exenatide plays an important role in the control of type 2 diabetes as a GLP-1 receptor agonist²⁸. Exenatide is used clinically as a twice daily subcutaneous injection at a dose of 10 µg²⁹. A longer acting form of Exenatide has been developed³⁰.

Another GLP-1 receptor agonist that has reached the market is Liraglutide^{31, 32}. Clinical trials with Liraglutide have shown a decrease in HbA1C levels and a decrease in body weight of diabetic patients, thus playing an important role in glycaemic control³³.

DPP-IV inhibitors: The inhibitors of the enzyme DPP-IV play an important role as they prevent early degradation of the incretin hormones, thus preserving the incretin effect³⁴. Animal studies revealed that DPP-IV inhibitors had a protective effect on both native and exogenous GLP-1, and enhanced the glucose-stimulated insulin release³⁵. Numerous human clinical trials have proved the effectiveness of DPP-IV inhibitors^{36,37}.

DPP-IV inhibitors in the market now include Sitagliptin and Vildagliptin^{36, 37}. They are oral anti-diabetic agents. Since the action of these drugs last for a long duration, Sitagliptin is given once a day and Vildagliptin twice a day¹⁷. There is improved control of blood sugars when these drugs are given along with other anti-diabetic medications¹⁷. Recent reviews have concluded that both Sitagliptin and Vildagliptin are well tolerated^{34,38}.

Conclusion: Incretin effect refers to the increased glucose-stimulated insulin secretion due to hormones secreted from the gastrointestinal tract. The two main incretin hormones are GLP-1 and GIP. Though the incretin effect is severely reduced in type 2 diabetic patients, the insulinotropic effect of GLP-1 is preserved. As GLP-1 is degraded rapidly by the plasma enzyme DPP-IV, GLP-1 receptor agonists and DPP-IV inhibitors enhance glycaemic control in type 2 diabetic patients.

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